

# **CARRIER SUITABILITY TEST ON LAND**

**SP 1528**

*Lockheed Aircraft Corporation*

**ADVANCED DEVELOPMENT PROJECTS**  
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**TITLE** CARRIER SUITABILITY TESTS ON LAND

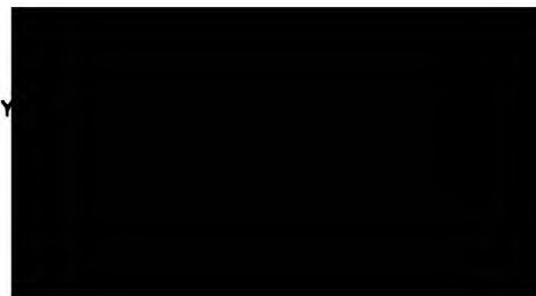
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DATE	PAGES AFFECTED

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SUMMARY

Carrier suitability tests on land were conducted on the U2-R in August and September 1969. An attempt to accomplish the test using a Mark 21 arresting gear at Edwards North Base was unsuccessful. The Mark 21 was not compatible with the U2-R performance because runouts were excessive.

The program was moved to Lakehurst Naval Air Station and the tests completed using a Mark 7 Mod 2 arresting gear, which is the same equipment used on the "Kitty Hawk" class carriers. Ten taxi arrestments and two landing engagements were made at Lakehurst.

Airplane landing and engaging performance were classified satisfactory. The airplane is considered ready to continue with a qualification program aboard a carrier.

## INTRODUCTION

The U2-R model specification SP-1125 stipulates that the airplane shall be designed for operation from Kitty Hawk class carriers (CVA 63, 64 & 65). A test program on land was conducted utilizing airplane serial number 055 to demonstrate the carrier suitability of the airplane. The tests were programmed to include an evaluation of taxi engagements, approach and touchdown technique and fly in arrestments.

Approach technique development tests were conducted at Edwards North Base on August 20 and 21, 1969. Satisfactory arrestment gear was not available on the West Coast and the taxi and fly in engagements were conducted at Lakehurst, New Jersey, on September 4 and 5, 1969.

The tests included evaluation of go around characteristics, airplane nose and runway clearance during runout, and potential damage to the aft section from the arresting cable.

Piloting duties for the test were shared by an LAC pilot and a Customer pilot. Taxi tests and technique development tests were flown by the Company pilot. At the time of these tests there were no carrier qualified Company pilots available so the actual flight arrestments were accomplished by a Customer pilot with prior U2-G carrier experience.

## DESCRIPTION OF TESTS

### MARK 21 TESTS

Arresting hook kit RX-107 was installed on U2-R serial number 055 in preparation for arrestment qualification tests. This kit consists of a hook assembly, hook cover assembly, tail gear door and tail wheel deflectors. The airplane test weight was maintained below 22,000# for the actual cable arrestments.

A Mark 21 arrestment gear was installed at Edwards North Base for the initial taxi tests into the arresting cable. This gear has a range of operating settings of zero to 15, with retardation increasing as numbers increase. The airplane configuration simulated the carrier touchdown configuration of spoilers out, speed brakes out and flaps set at 50 degrees. The arresting gear was initially set at five. Only a very light drag was noted by the pilot when the wire was contacted at 30 knots with a resultant runout of 400 feet. The Mark 21 setting was increased to ten and the contact speed was increased to 40 knots. Cable runout was 329 feet. In an effort to further reduce the cable runout the maximum setting of 15 was tested. Cable runout at 52 knots was 350 feet.

These runouts were excessive and it was evident that the Mark 21 gear was not compatible with the low speeds and weights of the U2-R. Since no acceptable arresting gear was immediately available locally, the taxi arrestment program was discontinued and the test emphasis was shifted to the development of approach and touchdown techniques.

# AIRPLANE TRIM AND STALL

The stall and trim characteristics were evaluated as a preliminary to the low speed flight activity. The results are shown in the accompanying table.

## Trim:

<u>IAS</u>	<u>CONFIGURATION</u>	<u>WHEEL POSITION</u>	<u>REMARKS</u>
150K	Faired	1 degree right	Zero force
150K	Gust	2 degrees right	Zero force
180K	Faired	1 degree left	Light force
200K	Gust	Zero	
230K	Gust	5 degrees left	
245K	Gust	7 degrees left	
260K	Gust	15 degrees left	20# force

The stall speed with 50 degree flaps and a 23,000# airplane weight was 64 knots. At approach to the stall the airplane had a tendency to yaw left and at the stall to drop the left wing. When the lift spoilers were raised, the stall speed increased two knots. At 85% RPM and 76 knots, the airplane maintained level flight and when the RPM was reduced to 81%, the rate of descent was 300 feet per minute.

It was agreed at this time by both pilots that the airplane was satisfactory for conducting runway arrestment qualification tests since the trim characteristics were acceptable in the low speed and approach configuration. The high speed trim characteristics although within acceptable limits, were not considered representative of the normal U2-R.

### APPROACH TECHNIQUE

Both pilots and a landing signal officer worked together on the runway passes to evaluate approach and engagement technique. A landing assist mirror set at 2 degrees slope was used during all the runway tests. At this glide slope the extended hook to ramp clearance at the approach end of the carrier is at least seven feet. The airplane configuration was 50 degree flaps, speed brakes out, and gear down.

Computer simulation studies of the arrestment operation indicated that less airplane nose oscillation would be encountered if the lift spoilers were already in the up position prior to engine cut. This procedure was ruled out after considerable evaluation because of moderate buffet and the lack of a speed controlling device during approach and landing. Best results were achieved from the lift spoilers by actuating the throttle push button switch as soon after the throttle was cut to idle as the pilot deemed advisable to enable him to round out and arrive in a two point attitude just prior to runway contact. If the airplane is fast, the pilot actuates the spoiler earlier. The RPM may be held approximately one percent high and throttle joggling avoided on the approach by actuating the spoilers momentarily to keep the speed down. There is a 0.5 to 1.0 second delay in spoiler activation after the switch is actuated, which must be anticipated by the pilot.

The desirable air speed at throttle cut was found to be 69 knots plus one knot per 100 gallons of fuel remaining.

The airplane fuel must be balanced to accommodate this technique and the low approach speeds. Lateral and directional control are adequate, but constant attention is required. Up drafts and down drafts affect the airplane



APPROACH TECHNIQUE (Cont.)

and turbulence such as ship's wake at ship speeds above 25 knots will make exact speed control difficult. If the airplane is allowed to wander off center line excessively during the last stages of the approach, the engagements must be discontinued since an "S" turn would be required to return to the center line.

Four full stop landings were made with the hook extended (no arrestment gear) to check hook bounce and none was noted. The hook snugged to the runway during the entire rollout.

The waveoff characteristics of the U2-R were evaluated and were considered acceptable for carrier operation. The higher approach RPM and slower approach speed made the U2-R superior to the U2-G in this respect.

The tests indicate that the following procedure should be used as a guide for Mirror Landing Practice:

CONFIGURATION:

Mirror glide slope 2 degrees

Wind zero (adjust IAS if wind is not zero)

Gear down

Speed brakes out

Wing flaps 50 degrees

Spoilers arm and landing

The RPM & IAS listed is intended as a guide and will require adjustment to varied conditions.

APPROACH TECHNIQUE (Cont.)

DOWNWIND:

Altitude: 400 feet  
RPM: 84 - 86%  
IAS: 82 - 85 knots

BASE:

350 feet descending  
RPM: 81 - 83%  
IAS: 78 - 80 knots  
Meatball pickup 1/2 way through. IAS 76 - 78 knots.

FINAL:

IAS: 74 - 75 knots  
Maintain 2 degree glide path  
Cut one; 69 knots plus 1 knot per 100 gallons

MAIN LANDING GEAR MODIFICATION

The metering pin in the main landing gear strut was modified to increase the energy absorption characteristics of the gear at initial ground contact. The new pin also reduced the gear load and stroke, and additional margin was provided to avoid possibility of ground contact of the nose section during arrestment.

A series of ten touch and go landings including a landing which the pilot purposely made harder than any of his previous U2-R landings, were made to evaluate the main landing gear. The pilot noted significant improvement in the gear although the original gear was considered satisfactory.

MAIN LANDING GEAR MODIFICATION (Cont.)

When observed from the runway the gear appeared to be very forgiving of a hard landing and seemed to have a tendency to snug the wheels to the deck. A comparison of the before and after MLG characteristics are shown in figure 7.

The taxi arrestments and landing arrestments were made with the modified metering pin installed.

ARRESTING TESTS

The Naval Air Test Center at Lakehurst was chosen as the test site for continuation of the arrestment tests. Personnel and support equipment were loaded on a C-130 airplane and flown to the test site. U2-R, serial no. 055, was ferried to the site on the next day. The arrestment gear selected for the tests was a Mark VII Mod 2 hydraulic plunger type, with 1-3/8 diameter arresting cable. This installation was a duplication of that installed aboard carriers. The U2-R hook detent is for a 1-1/8 diameter cable, however, the 1-3/8 diameter cable was left on the arresting gear for the test since it was shown the low engagement speeds and weight of the U2-R would accommodate the larger diameter cable without disengagement or failure. The Mark 7, Mod 2 equipment provides a range of operating settings starting at 10X for aircraft weights of 10,000 pounds or less, and increasing in retardation capability with settings according to the actual weight of the airplane.

### TAXI ARRESTMENTS

The arresting gear aircraft weight selector was set at the lowest possible machine setting of 10X for the initial taxi arrestment because the U2-G arrestments were best at this setting. Also, the U2-R computer studies had been conducted with the 10X machine setting.

Ten taxi arrestments were made by the Company pilot. The winds were approximately three knots on the tail and there was a light rain.

The results are shown in the accompanying table.

### CONFIGURATION:

Wing flaps 50 degrees, spoilers out, hook down, RPM as required for ground speed. Speed brakes out. ZFW: 18,843#, c.g. 26.9%.

### FUEL:

Sump 100 gallons, outb'd 200 each, inb'd empty.

### CAMERAS:

Takeoff and land camera, 16 MM, 32 frames per second. 100 foot magazine with black and white film.

High speed photosonic, 16 MM, 240 frames per second, 200 foot magazine with black and white film (two cameras; one viewing the hook and one viewing the main landing gear strut).

High speed photosonic, 16 MM, 24 frames per second, 200 foot magazine with black and white film, camera viewing forward to monitor nose section oscillation.

TAXI ARRESTMENTS (Cont.)

CAMERAS: (Cont.)

Aeroflex 16 MM documentary hand held runway operated camera with color film, at 24 frames per second.

Two Aeroflex 16 MM documentary hand held runway operated camera (NATF supported) with color film at 64 frames per second.

Hulcher 70MM runway operated camera with black and white at 10 frames per second.

RESULTS:

Run	Airplane Weight Lbs.	Ground Speed Knots	Airplane Runout Ft.	Arresting Gear Setting A/C Wt. Lbs.	Remarks
1	22,000	39.6	177	10X	Wheel held slight aft
2	21,848	42.6	202	10X	Wheel slight aft. R.H. tail gear door contacted by wire. No Hulcher camera.
3	21,802	61.9	296	10X	R.H. tail gear door contacted by wire.
4	21,724	48.4	218	10X	Wheel full fwd.
5	21,482	57	280	10X	Wheel full fwd.
6	21,404	50.4	223	12,500	Neutral wheel
7	21,313	53.1	252	15,000	No hook OK. Hulcher camera. Wheel neutral.
8	21,235	57	235	17,500	Neutral wheel. Slight nose down pitch.
9	21,157	55.1	232	20,000	Wheel neutral, slight nose down pitch.
10	21,066	77.5	280	20,000	Flaps up, full nose down trim, slight nose pitch (R.H. dive flap slight contact with wire) (Speed high due to ground radar inaccuracy)

### TAXI ARRESTMENTS (Cont.)

The airplane was very stable on all 10X arrestment settings, but the run-outs were excessive. Arresting gear settings were increased in 2500 pound increments until it was determined that an acceptable setting would be at approximately the gross weight of the airplane. At the higher machine settings and engagement speeds, a mild pitch down of the airplane nose occurred during runout. A GSN5 radar was used to measure airplane approach speeds. These speeds were called to the pilot to assist him in attaining his target speeds. Moderate arresting cable contact of tail gear doors, fiberglass and polyurethane fairings and lower edges of speed brake doors was noted during the high speed runs. The arresting hook was worn in the taxi runs till the attaching bolt was partially ground off. Both bolt and hook were replaced after thirteen runs on concrete runways.

The hook action and runout characteristics of the airplane were satisfactory and it was determined that the airplane was ready for wire engagements from flight.

### LANDING ARRESTMENTS

The customer pilot made five fly-bys with the hook retracted and arresting gear unstrung for pilot and landing signal officer transition. There was a six-knot tailwind. The cable was then strung and two fly-in arrestments were made.

The stability of the airplane during runout was good and nose to runway clearance was only moderately compromised.

LANDING ARRESTMENTS (Cont.)

After initial runway contact the arresting hook snugged to the runway and was only momentarily and slightly deflected by runway projections.

Damage inflicted by the arresting cable required replacement of the left tail gear door and actuating rod, fiberglass fairing RL 101-4 and polyurethane hook fairing RL 101-5. See figures 4 through 6.

The airplane and camera configurations were the same as for the taxi arrestments. The arresting gear setting was for an airplane weight of 2000 pounds.

Results of the runs are shown in the accompanying table.

<u>Run</u>	<u>Airplane Weight Lbs.</u>	<u>IAS (Knots)</u>	<u>Airplane Runout Ft.</u>	<u>Remarks</u>
1	22,400	82 (approx)	----	Pass was long - 79% ingroove holding right rudder.
2	22,120	74 (approx)	----	72 knots in close - no touch down.
3	21,770	72 (approx)	----	Touch & go - (Rough over steam plant, 1 mile out - smooth after)
4	21,570	74 (approx)	----	Touch & go - A little fast.
5	21,180	-----	----	Touch & go - OK.
6	20,950	76	270	Good arrest - 2-1/2 ft. right of center-line - Tail wheel 10 inches high at engage. Main squatted, pilot felt slight pitch down-70K at cut one. The spoilers were delayed slightly and the nose eased down a shade to avoid flaring too high. Six knot tail wind.
7	20,860	78.7	274	72 knots at engine cut. (Six knot tail wind) Spoilers were popped almost immediately after engine cut. A slight float was experienced and the wire was engaged while main and tail gear were six inches above the runway. Arrestment was smooth with maybe a shade more nose down pitch, but "eminently satisfactory" per pilot.

LANDING ARRESTMENTS (Cont.)

The airplane runouts and handling characteristics observed on these arrestments indicate that the U2-R is ready for qualification tests aboard a carrier.

Maximum airplane runout is not expected to exceed 230 feet. This airplane runout will require the fourth wire to be removed from carriers CVA 63, 64 and 65 to avoid the left wing tip from extending over the port deck edge. Runout of cable number three to 230 feet on these carriers will result in six foot clearance of the wing tip and deck edge if the arrestment is on the center line. On carrier CVA 65 a center line engagement on the number three cable will result in twelve foot clearance of the deck edge. See figures 14 & 15.



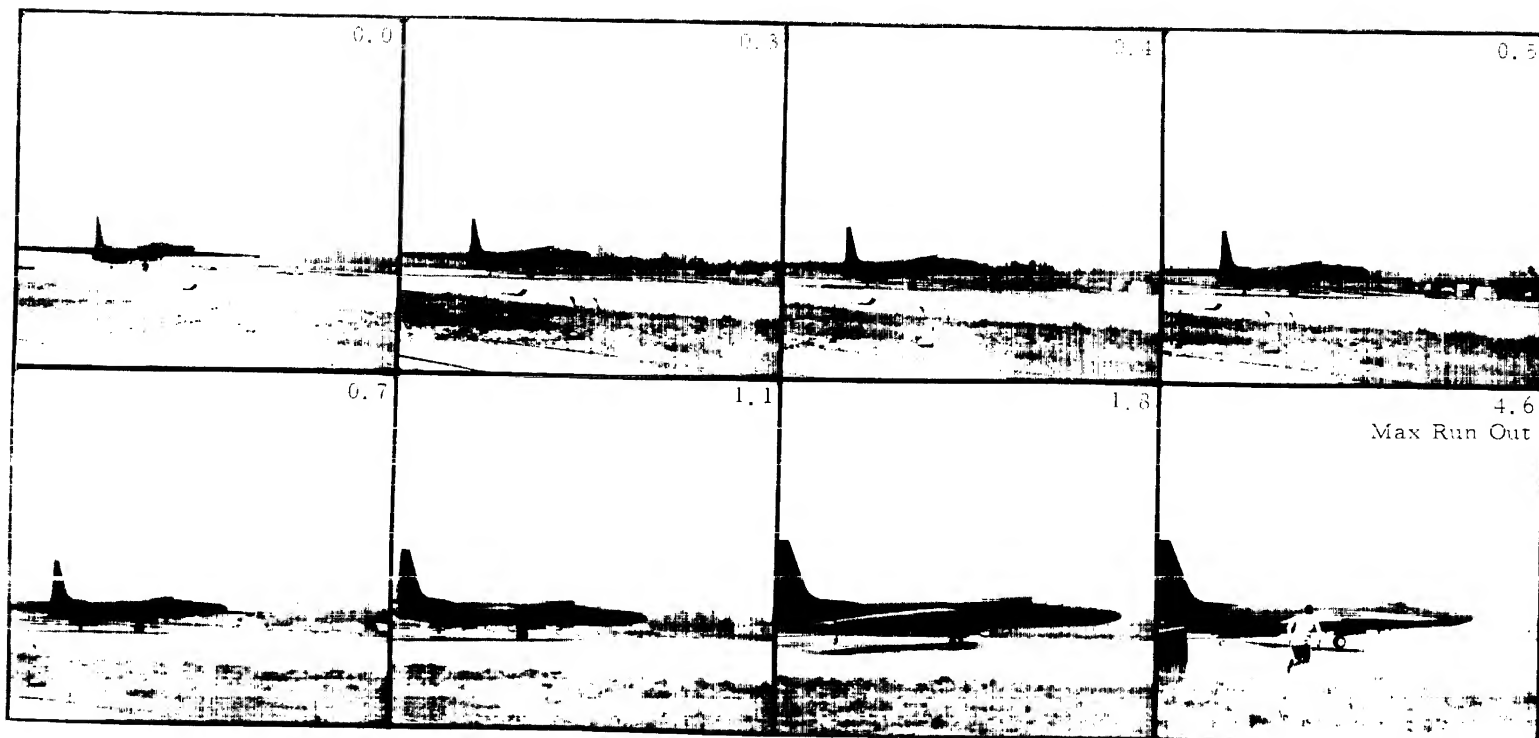
## CONCLUSIONS AND RECOMMENDATIONS

1. The runway arrestment tests indicate that the airplane is ready for qualification tests aboard a carrier. Maximum airplane runout should not exceed 230 feet. Three wires can be used on carriers CVA 63, 64 and 66. With this runout, using the third cable, six feet of clearance from the left wing tip to the deck edge exists if the engagement is on the center line. CVA 65 will allow twelve feet of clearance on a center-line engagement and 230 feet runout. The arresting gear should be set at 20,000 lbs airplane weight for the initial landing, with further adjustments only if required.
2. The U2-R arresting hook can accommodate safely the 1-3/8 diameter arresting cable which is standard on the Mark 7, Mod 2 arresting gear.
3. The landing signal officer and pilot must work together during the approach to maintain optimum speed and altitude. The LSO will call for the first cut (throttle to idle) and the pilot will continue the descent raising the spoilers as necessary to round out in a two-point attitude just prior to touchdown.
4. Moderate damage to tail gear door assemblies and hook fairings can be expected during arrestment. Spares should be provided for these components.
5. Airplane nose structure ground clearance during runout is satisfactory.
6. The wave-off capability of the U2-R is satisfactory for carrier operation.

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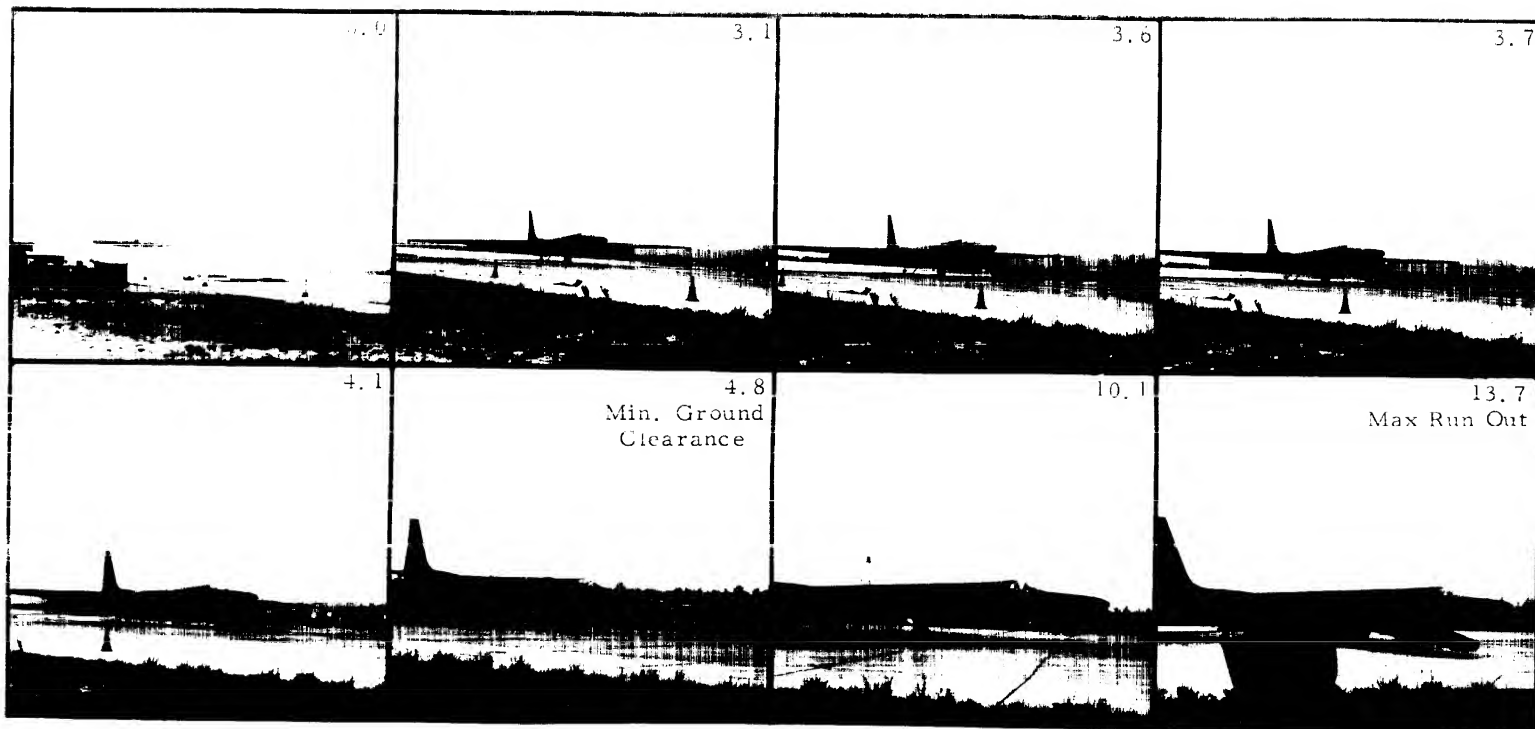


7273-4

FIGURE 1 TAXI ARRESTMENT  
 ARRESTING GEAR SETTING 20,000  
 ENGAGEMENT SPEED 77.5 KNOTS  
 RUNOUT DISTANCE 280 FEET  
 AIRPLANE WEIGHT 21066 LBS

TIME INTERVAL IS ELAPSED TIME IN SECONDS AFTER FIRST FRAME

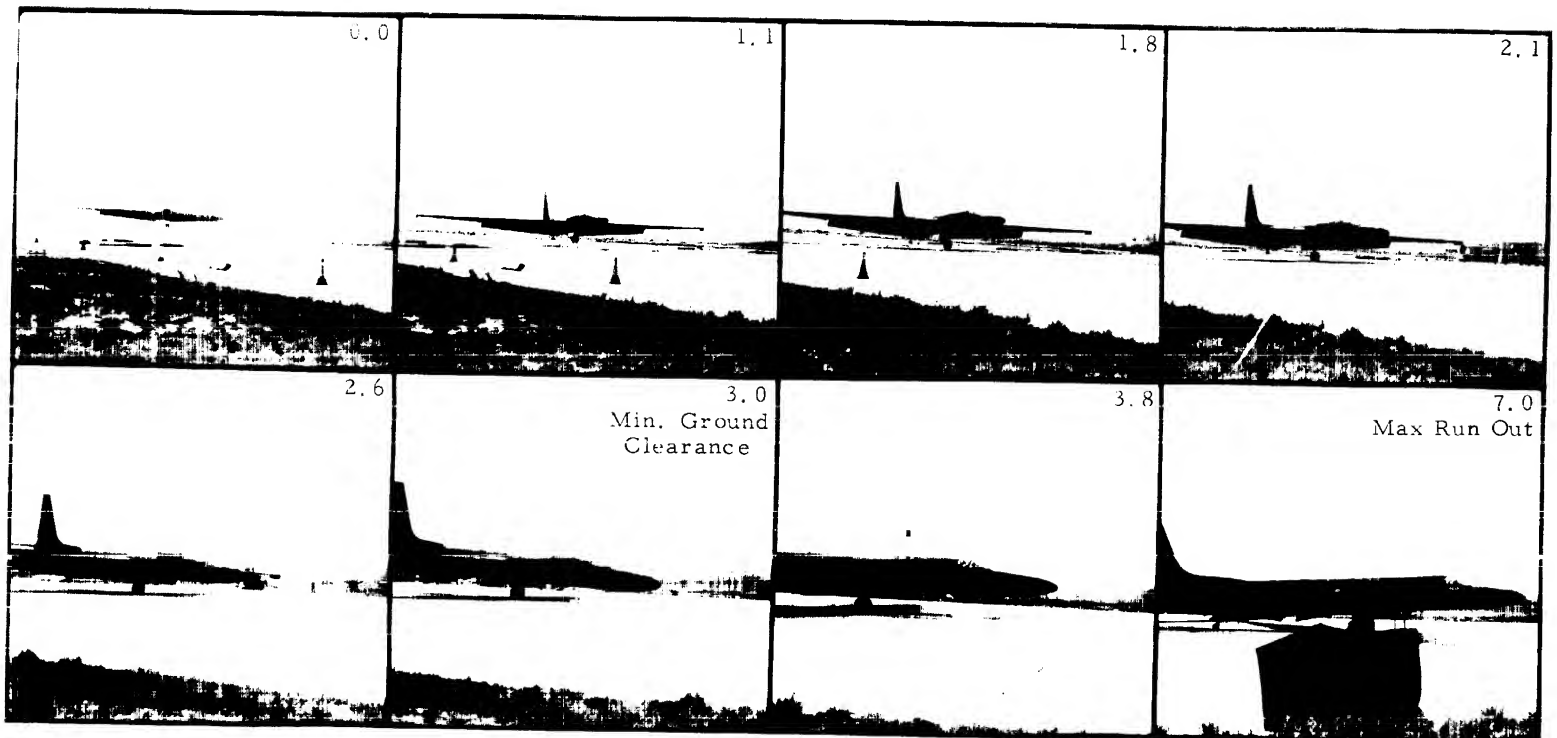
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7273-5

FIGURE 2 FLY IN ARRESTMENT NUMBER ONE  
 ARRESTING GEAR SETTING 20,000  
 ENGAGEMENT SPEED 76 KNOTS  
 RUNOUT DISTANCE 270 FEET  
 AIRPLANE WEIGHT 20950 LBS

TIME INTERVAL IS ELAPSED TIME IN SECONDS AFTER FIRST FRAME



7273-6

FIGURE 3 FLY IN ARRESTMENT NUMBER TWO  
 ARRESTING GEAR SETTING 20,000  
 ENGAGEMENT SPEED 78.6 KNOTS  
 RUNOUT DISTANCE 274 FEET  
 AIRPLANE WEIGHT 20860 POUNDS

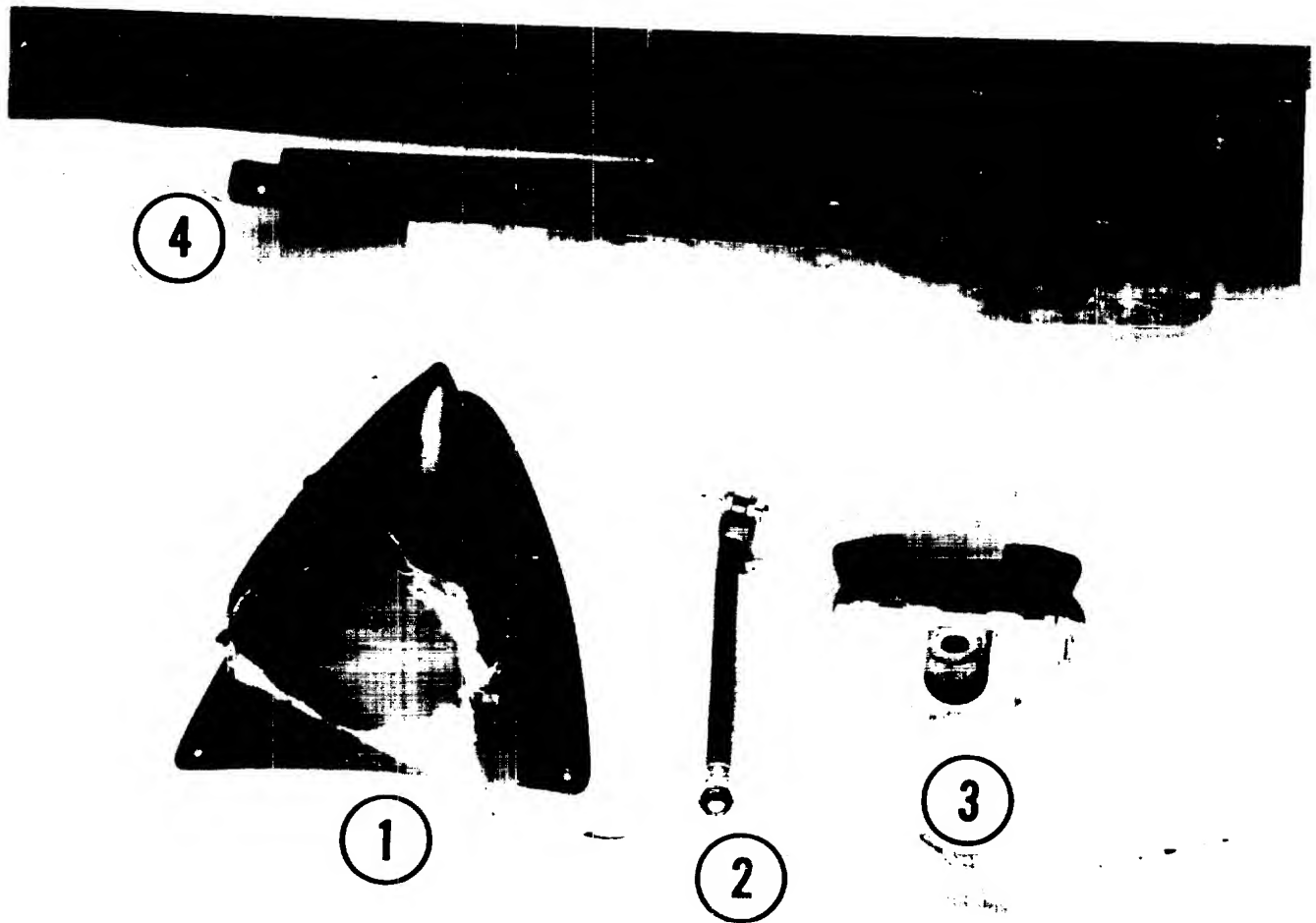
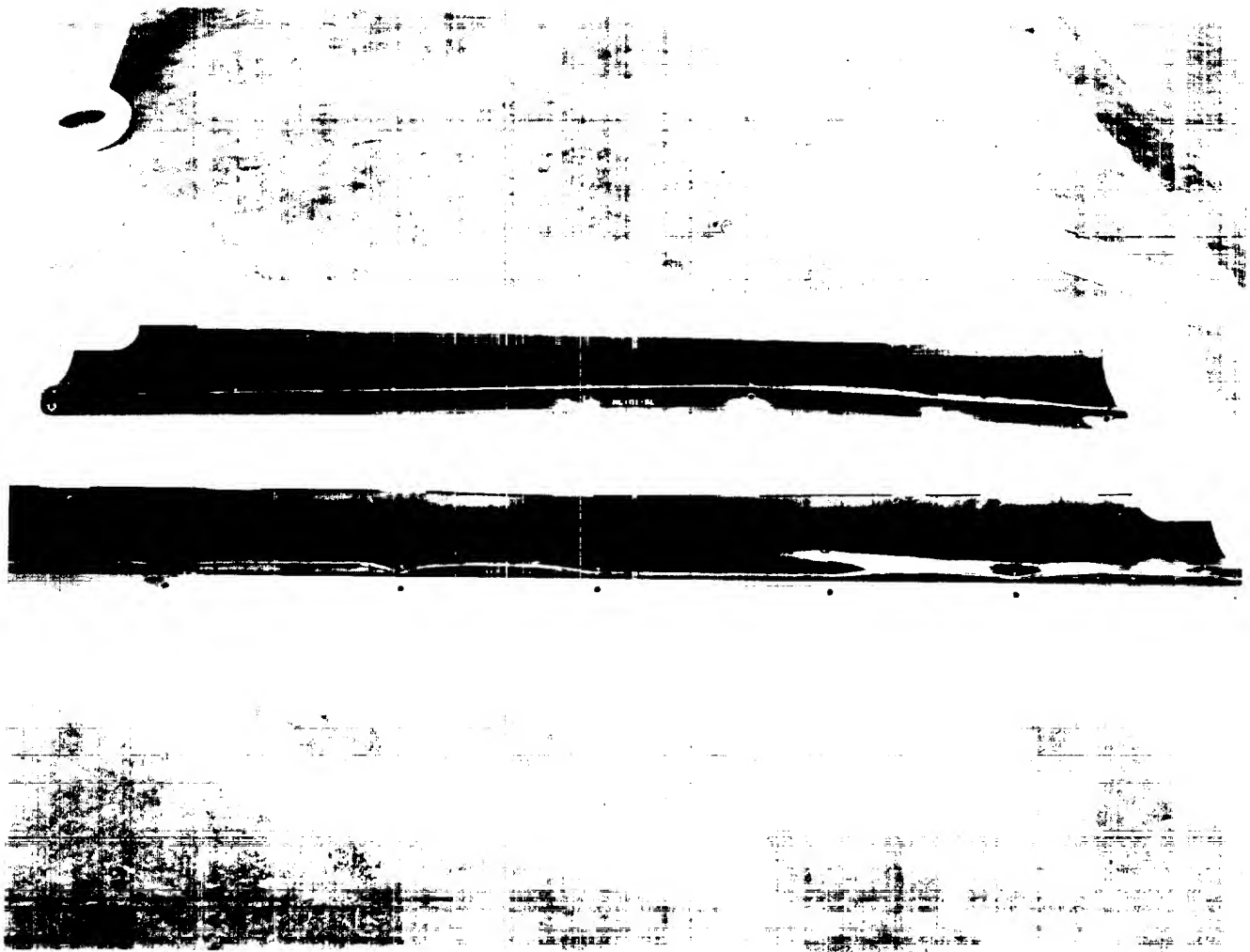


FIGURE 4 DAMAGED PARTS

7.73-2

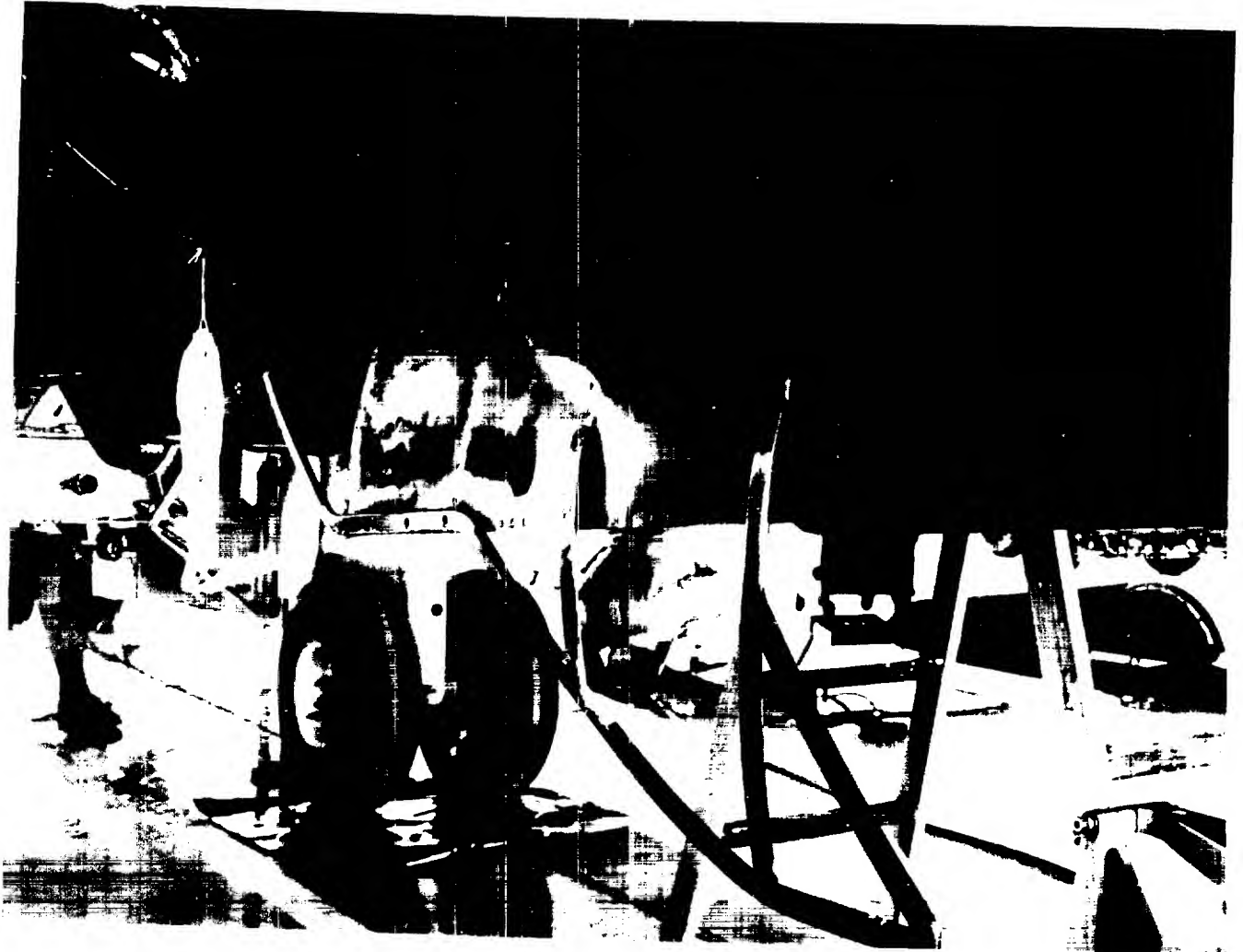
- ① RL 101-4 FIBERGLASS FAIRING
- ② LH TAIL GEAR DOOR ACTUATING ROD BENT BY ARRESTING WIRE ON SECOND ARRESTMENT
- ③ HOOK AFTER THIRTEEN TAXI ENGAGEMENTS - DRAGGING ON CONCRETE RUNWAYS.
- ④ POLYURETHANE HOOK FAIRING RL 101-5.



7273-1

FIGURE 5 DAMAGED PARTS

RL101-5 POLYURETHANE FAIRING AND SHEET METAL MOUNTS  
DAMAGED AS RESULT OF ARRESTING HOOK ARM STRIKING  
AGAINST BUMPER ON BOTTOM OF FUSELAGE DURING EN-  
GAGEMENT.



7-73-3

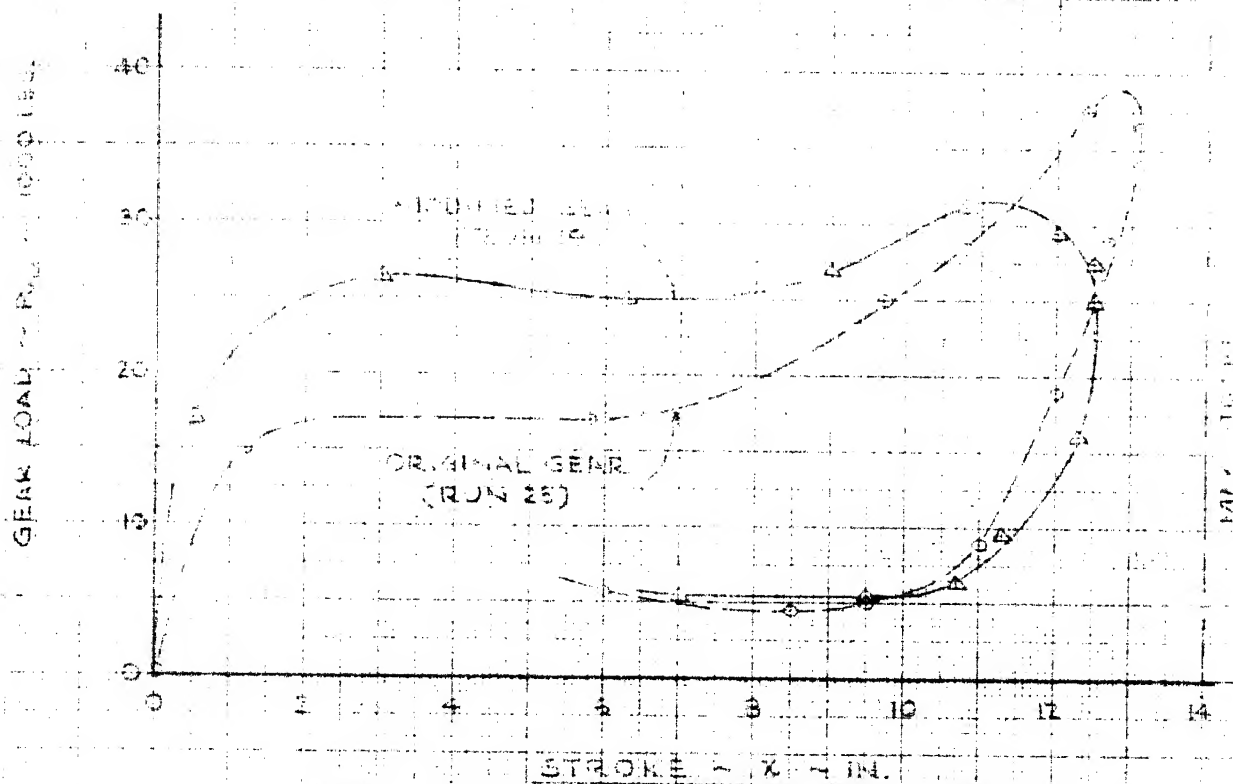
FIGURE 6 DAMAGED PART

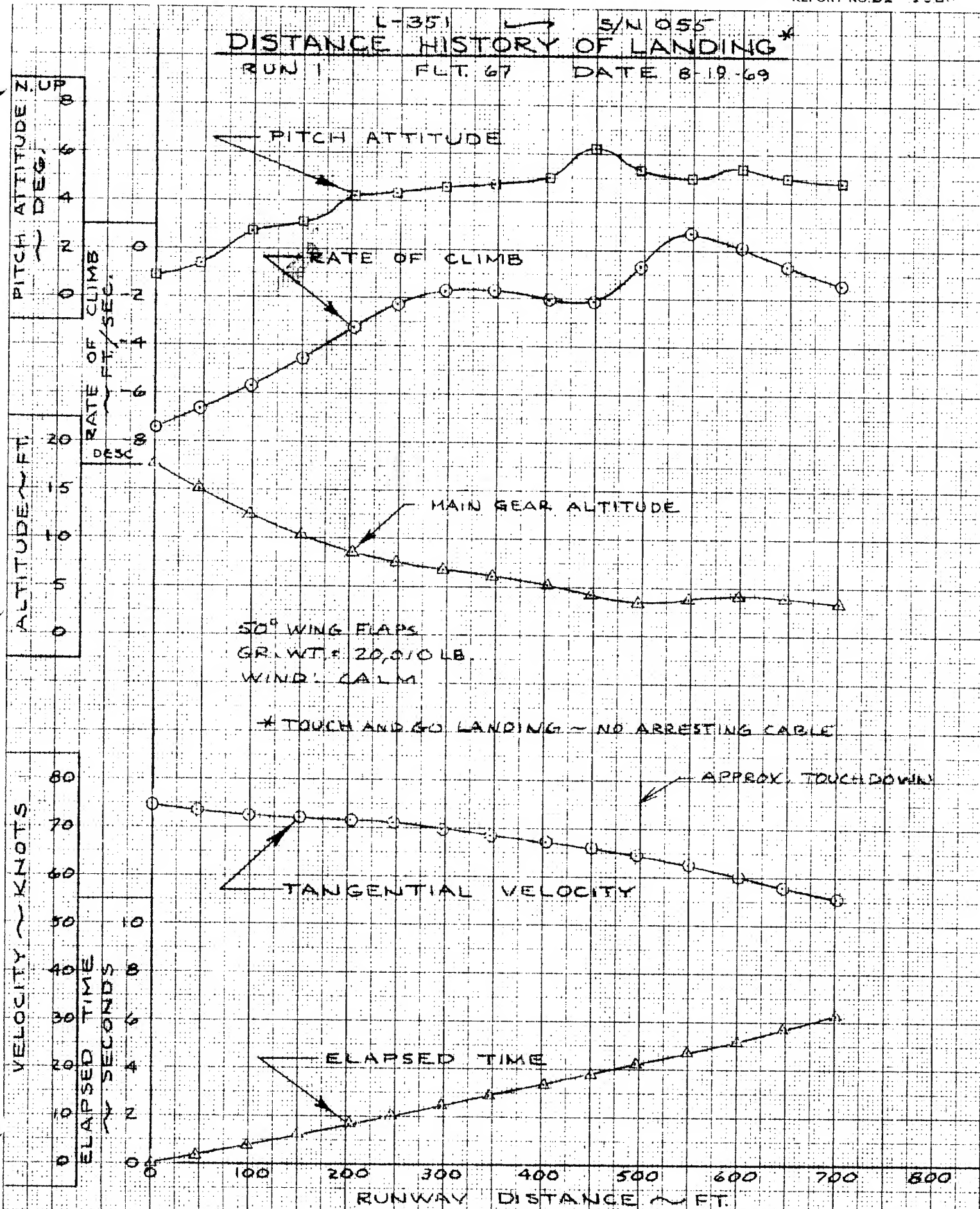
LEFT HAND TAIL WHEEL DOOR DAMAGE FROM ARRESTING WIRE  
AS RESULT OF SECOND FLY IN ARRESTMENT



# VE-7 TRAIN GEAR LOAD STROKE GRAPH

AIRPLANE GWT = 2200 LBS.  
 ENGAGING SPEED = 53.5 RPM  
 SINK SPEED = 10 FPS



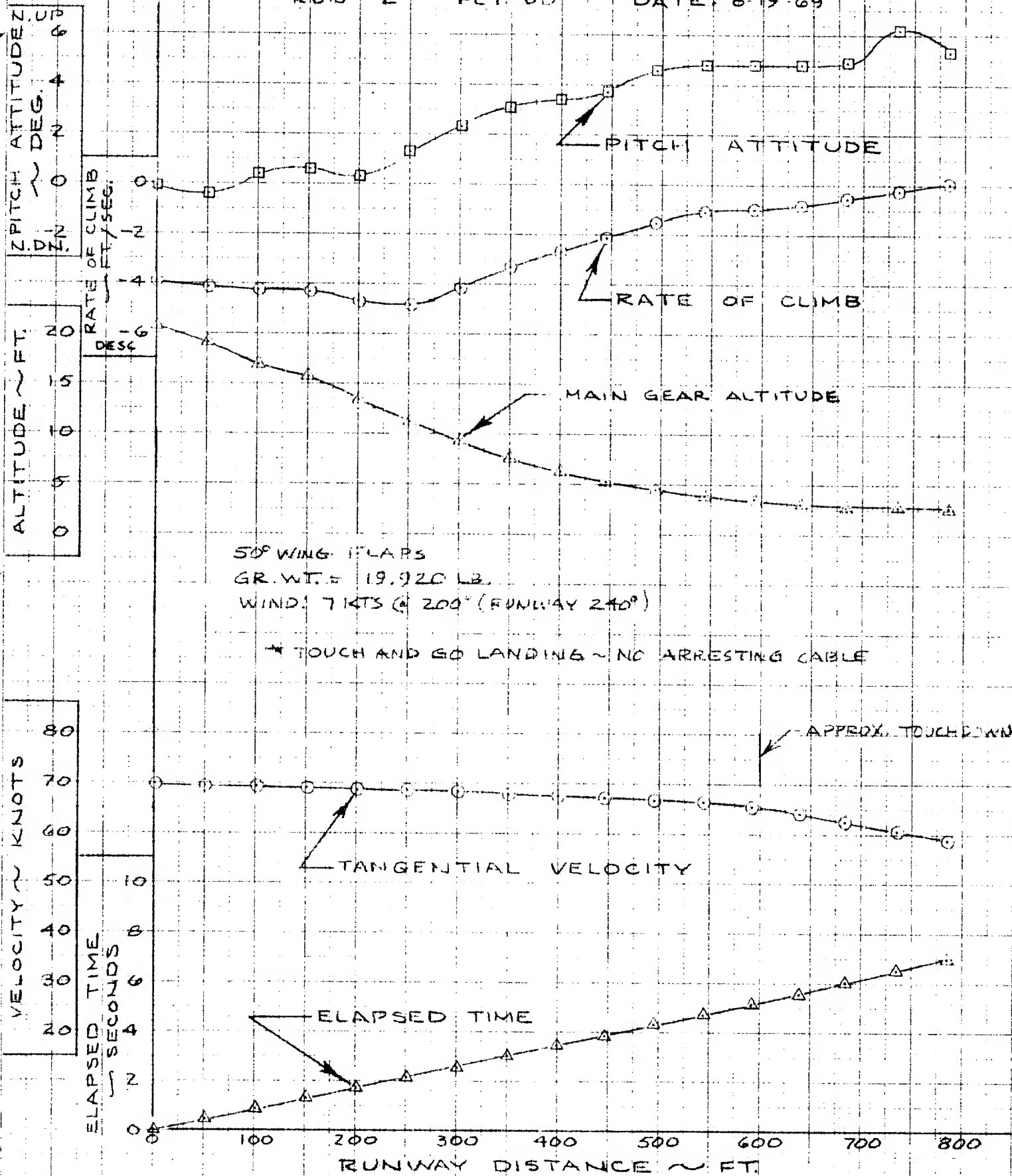


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L-351 ~ S/N 055

# DISTANCE HISTORY OF LANDING\*

RUN 2 FLT. 68 DATE: 8-19-69

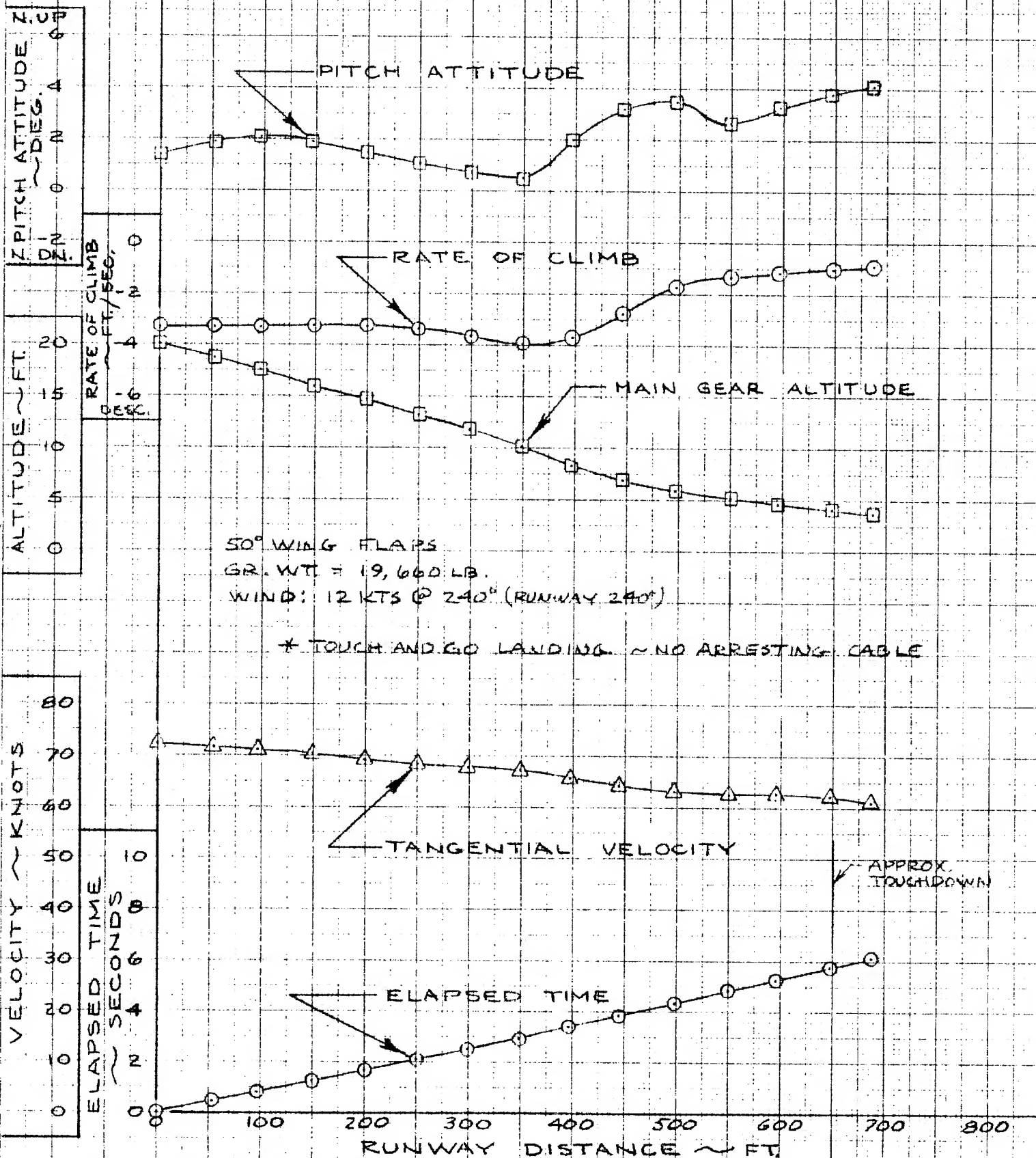


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FIGURE 9

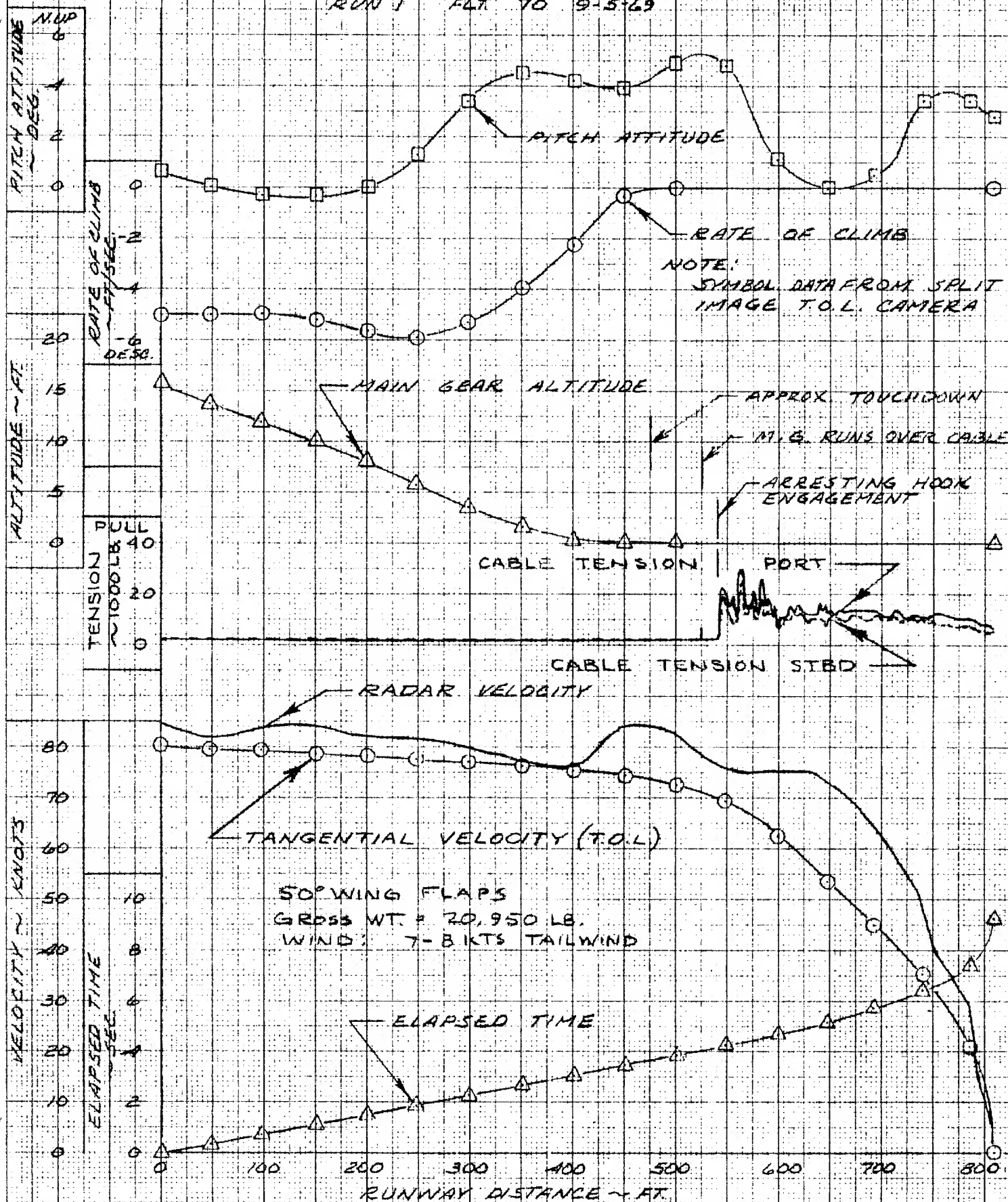
# L-351 S/N 055 DISTANCE HISTORY OF LANDING\*

RUN 3 FLT 68 DATE: 8-19-69



L-351 ~ SIN 055  
DISTANCE HISTORY OF LANDING ARRESTMENT

RUN 1 FLT TO 9-5-69



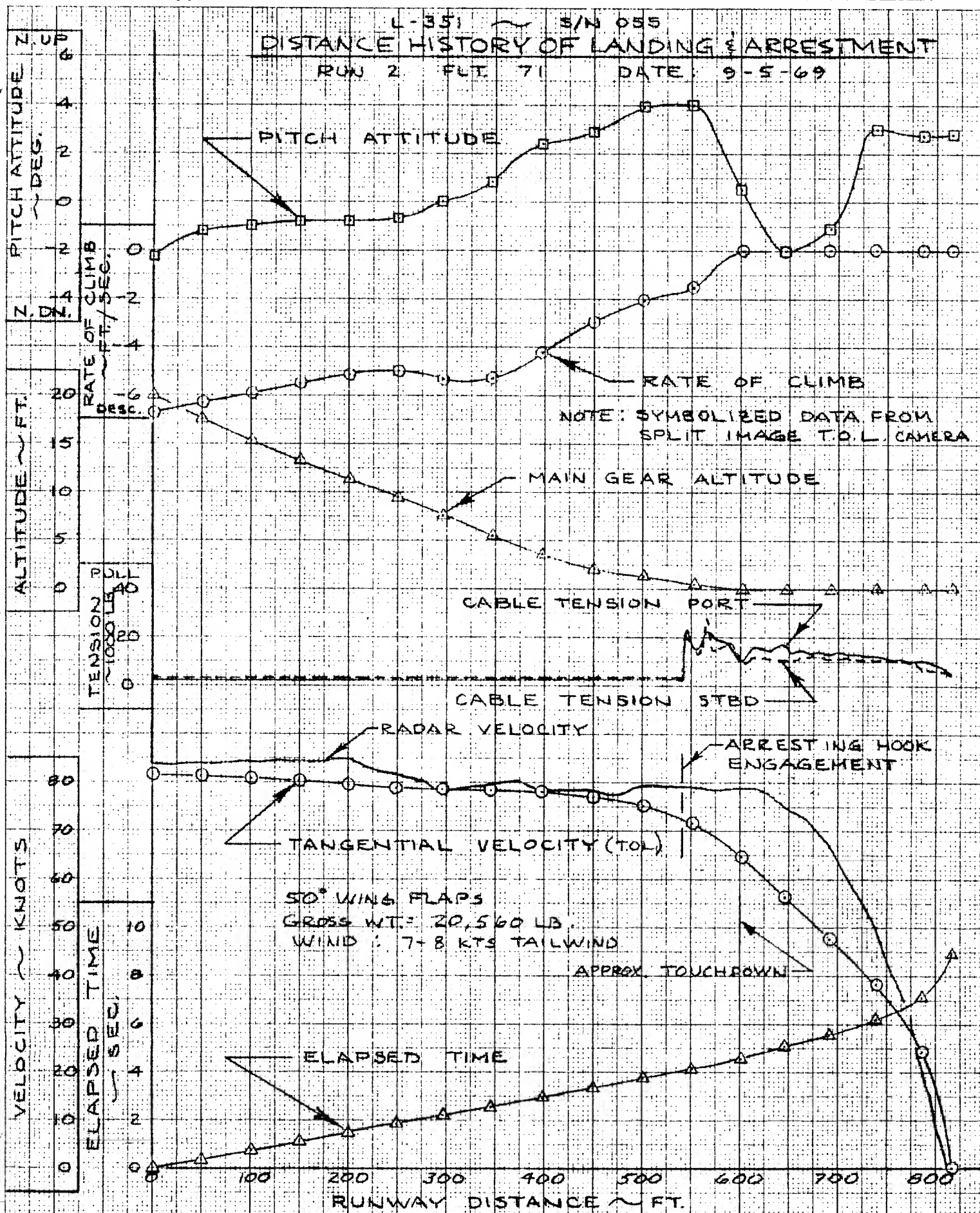
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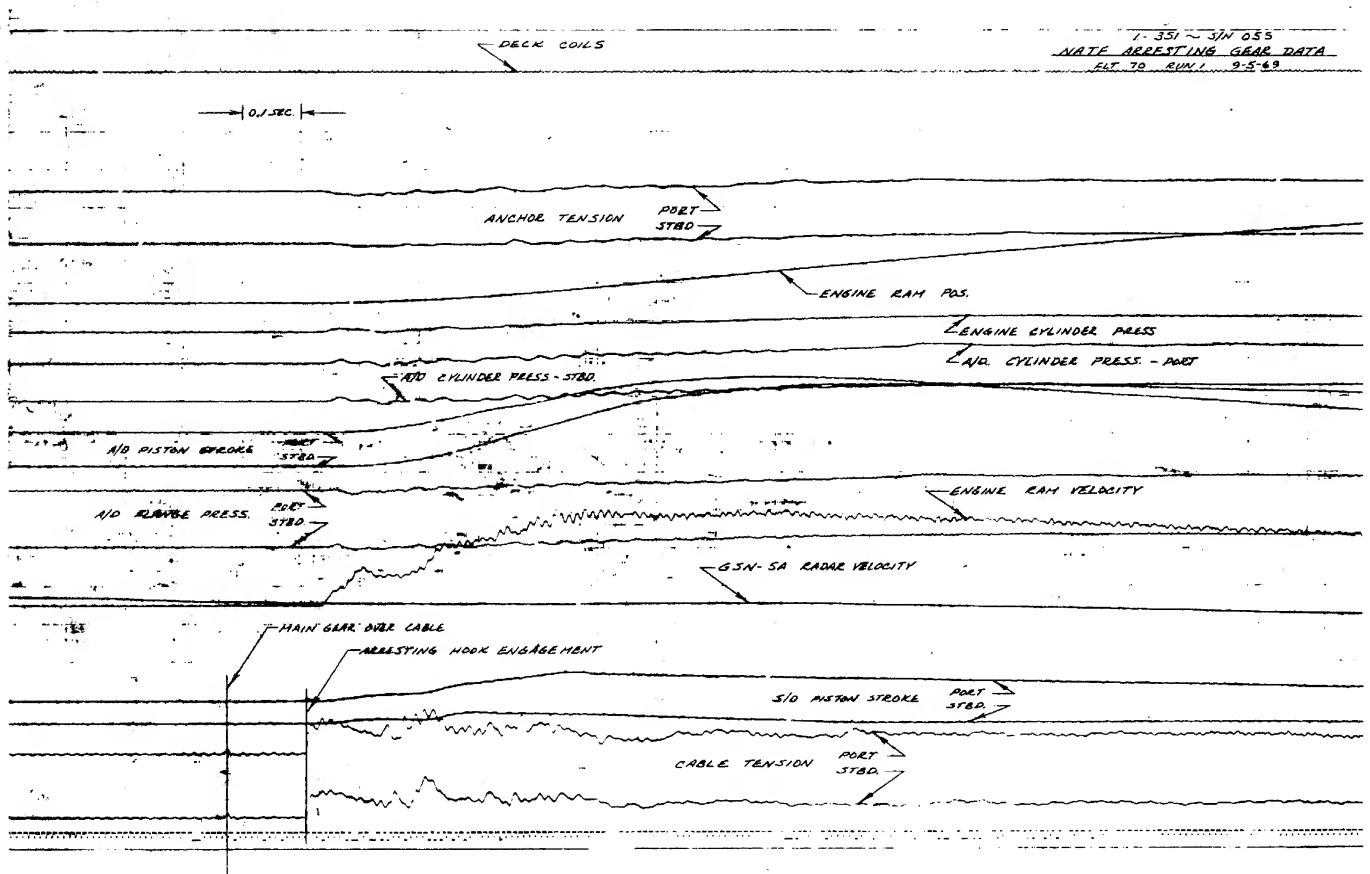


L-351 ~ S/N 055

# DISTANCE HISTORY OF LANDING & ARRESTMENT

RUN 2 FLT 71 DATE 9-5-69





NATF ARRESTING GEAR DATA  
FIGURE 13





